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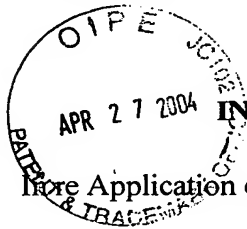
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Re Application of

Stephen Philip CHEATLE

U.S. Patent Application No. 10/697,640

Filed: October 31, 2003

For: IMAGE CAPTURE SYSTEM AND METHOD

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TRANSMITTAL OF CERTIFIED PRIORITY DOCUMENT

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Sir:

At the time the above application was filed, priority was claimed based on the following application(s):

GB Application No. 0225145.9, filed October 31, 2002.

A copy of the priority application is submitted herewith.

Respectfully submitted,

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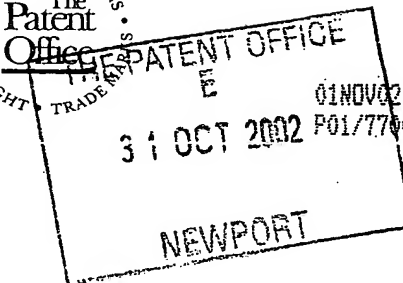
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1. Your reference 200206439-1 GB

2. Patent application number
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0225415.9

31 OCT 2002

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Hewlett-Packard Company
3000 Hanover Street
Palo Alto
CA 94304, USA

Patents ADP number (if you know it)

Delaware, USA

496 588001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention Image Capture Systems using Motion Detection

5. Name of your agent (if you have one)

Richard A. Lawrence
Hewlett-Packard Ltd, IP Section
Filton Road, Stoke Gifford
Bristol BS34 8QZ

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

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11.

I/We request the grant of a patent on the basis of this application.

Signature
Richard A. Lawrence

Date 31/10/02

12. Name and daytime telephone number of person to contact in the United Kingdom

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DUPLICATE

Image Capture Systems using Motion Detection

This invention relates to an image capture system that uses at least one motion sensor.

5

It is known for a user to wear a head mounted camera, which points in the direction that the user's face is facing, so that images can be captured of roughly what the user is looking at.

10

This type of set-up does not allow for the user moving his eyes relative to his head, causing resultant images to often be poorly framed.

15 Head-mounted cameras are well known, such as that described in W09949656 (Mann). The system described in Mann assumes that the head direction is the correct direction for image capture. Any control of what is captured needs to be done by consciously pointing the head
20 in the direction of interest. Sophisticated wearable camera systems such as described as Mann, are coupled with a wearable view finder to provide the wearer with confirmation that what the camera is seeing is what is required.

25

In Wearable Visual Robots (IEEE International Symposium on Wearable Computing, ISWC'00, Atlanta, October 2000) a wearable visual robot is disclosed having a pan/tilt mechanism. The work described mounts the apparatus on a
30 wearer's shoulder. The device has motion sensors attached to it, but there are no sensors attached to the wearer's head, so the device is unable to take into account the motion of the wearer's head. The aim of the approach in

this document is to provide a sensor which "decouples camera movement from the wearer's posture and movements". The aim is to allow the robot itself to choose what to look at. The motion sensors are provided to increase its
5 ability to stabilise its line of vision on what the robot decides should be captured, regardless of where the user's attention is focussed.

Several alternatives have also been proposed for capturing
10 a panoramic image of a scene. These include US 614034 which discloses a dodecahedral arrangement of sensors whose images can be combined into a single panoramic image. Also, US 6356296 describes the use of a parabolic reflector to capture an entire 180° angle of view using a
15 single sensor. The aim of both of these systems is to provide a very wide angle of view image. A problem arises with panoramic view capture in that it is not clear what part of the image is of interest. Typically a panoramic view will not all be interesting, but merely a part
20 thereof.

It is an object of the present invention to address the above mentioned disadvantages.

25 According to a first aspect of the invention an image capture system incorporates an image capture device and head motion detection means operable to detect motion of a user's head; wherein the image capture system is adapted to move a direction of a field of view of the image
30 capture device relative to the user's head, based on detected motion of the user's head.

The image capture device is preferably operable to be mounted on a user's head.

5 The head motion detection means are preferably adapted to be secured to a user's head.

The image capture system may be adapted to move, preferably rotate, the field of view of the image capture device relative to a direction of view of the user's face.
10

The head motion detection means may be mechanical head motion detection means, preferably at least one gyroscope and/or at least one compass.

15 The head motion detection means may be image analysis means operable to determine a motion of an object within a field of view of the image capture device to infer motion of a user's head.

20 The head motion detection means may incorporate a centering mechanism, which preferably takes as a centre position a position adopted by the motion detection means for a majority of the time.

25 The image capture system is preferably operable to control a direction of view of the image capture device with field of view control means, preferably to control a field of view by a lateral rotation.

30 The field of view control means may control at least one additional image capture device, preferably a lateral additional image capture device, preferably two lateral additional image capture devices. A lateral image capture

device may be an additional image capture device, preferably positioned such that an optical axis thereof is rotated in a horizontal plane relative to that of the first mentioned image capture device, preferably thereby
5 having a field of view which is horizontally rotated from the field of view of a main image capture device.

The or each lateral additional image capture device preferably has a field of view to one side of a main image
10 capture device that substantially partially overlaps with a field of view the main image capture device.

Images from the main and additional image capture devices may be buffered in a storage means for subsequent
15 retention of an image/images from one of said image capture devices.

The field of view control means may comprise a mechanism operable to adjust a direction of the image capture
20 device, preferably to adjust the direction from side to side. The mechanism may be a pan adjustment mechanism, or may be a pan/tilt adjustment mechanism.

The field of view control means may comprise at least one
25 mirror operable to be adjusted to adjust an image reflected to the image capture device. Preferably, the field of view control means comprises two mirrors. The field of view control means may be operable to adjust the or each mirror to move the image reflected to the image
30 capture device laterally.

The field of view control means may be operable to select a smaller image from a first image captured by the image

capture device. Said first image may be an image of substantially all of a user's lateral field of view, including the user's view with his eyes moved to one or both sides. The image capture device may incorporate a
5 wide-angle lens, which may be a fish-eye lens.

The image capture system may incorporate control means, which may be a computer or microcomputer, operable to activate the field of view control means on detection of
10 movement of the user's head. Preferably, on detection of movement of the user's head in a first direction by the head motion detection means, the control means is operable to activate the field of view control means to move a
15 direction of view of the image capture device in the first direction, by an amount in addition to the detected head motion.

An amplitude of movement of the user's head detected by the head motion detection means may be used to control an
20 amplitude of movement of the direction of view of the image capture device in addition to the detected head motion. The amplitude of movement of the field of view may be chosen to be of substantially the same amplitude as the amplitude of detected head movement.

25

A direction of detected head movement may be used to select an additional or lateral image capture device for providing the field of view.

30 According to a second aspect of the invention a method of capturing an image with an image capture device, comprises:

detecting motion of user's head; and

offsetting a field of view of an image capture device in a direction of the detected motion of the user's head.

5 The image capture device may be secured to the user's head.

Preferably, the detected motion is a rotation of the user's head, preferably a lateral rotation, to left or right.

10

The field of view may be offset by an amount derived from an amplitude of the detected motion, preferably in the range of approximately 30° to approximately 45°.

15 All of the features described herein may be combined with any of the above aspects, in any combination.

For a better understanding of the invention and to show how the same may be brought into effect, specific
20 embodiments will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic front view of an image capture device incorporating three separate image sensors pointing
25 at different angles and incorporating a motion sensor, for wear as a pair of spectacles;

Figure 1b is a schematic view from above of the device shown in Figure 1a;

30

Figure 2a is a schematic view from the front of an image capture device having a pan/tilt mechanism for adjusting

the field of view of the device, together with a motion sensor;

Figure 2b is a schematic view from above of the device
5 than in Figure 2a; and

Figure 3 is a partial schematic view of an alternative arrangement of image capture device having a switchable direction of view by means of pivotable mirrors;

10

Figure 4a is a schematic view from above of a camera having a fish-eye lens; and

Figure 4b is a schematic view and field of view selection
15 from a larger image.

It has been realised that when a person turns his head to look at a new stimulus his eyes are typically moved more quickly than his head so that as he looks to the side his
20 eye movement, combined with the head movement, rotates his direction of view by up to twice the angle of the head rotation alone. If a camera is fixed to a user's head then it will only rotate by the head movement, which results in the camera no longer capturing approximately
25 what the wearer is looking at. Below are described various embodiments by which an image sensing means can offset the direction of view of a captured image from the direction of a user's head, such that the direction of the image capture rotates in the same direction as the head,
30 but by a larger angle. This accomplished by sensing the rotation of the user's head, detecting when a turn to the left or right is occurring and moving the angle of view of the image sensing means so that it rotates further than

the rotation of the head alone, in the same direction as the head rotation.

The embodiments described disclose a system that adjusts the direction of image capture to take into account eye motion, rather than simply relying on head direction. This frees a user from having to think about what is being captured, because the wearable camera system will generally be capturing the area of visual attention more accurately than a conventional head mounted camera.

The embodiments described below all require the head rotation detection mechanism to control an additional change in the direction of view of the captured image beyond mere movement of the user's head. Also, an image capture device having a controllable field of view is required.

In relation to head rotation detection a first head rotation detection mechanism 10 is shown in Figures 1a and 1b mounted on a pair of spectacles 12 to be worn by a user 14. The head rotation detection mechanism 10 makes use of a mechanical motion sensor.

This may be in the form of a micro-compass which gives an absolute measure of the direction in which the detection mechanism 10 is pointing. Suitable calibration to a forward direction can be used to provide an angle of deviation from forward to indicate how much a user's head has moved. A suitable type of compass would be a Hall effect type, which may have a low accuracy as low as 45°, but may be sufficient to indicate that a person's head has moved to either right or left. Such a low accuracy device

has the benefit of low cost. A more accurate compass would be a Honeywell HMR 3200 model, which gives a half degree accuracy.

5 An alternative type of head rotation detection mechanism device 10 would be to use a miniature gyroscopic device, such as a Murata Enc 03J, which is of a piezoelectric type, in which a vibrating column is moved off-axis by acceleration of the device, which movement off-axis causes
10 current to flow in a piezoelectric device. With a gyroscope, the rate of movement need only be integrated to revert to an angle through which the accelerator has rotated. The amount of rotation is determined by integration of the signal.

15

The output of an accelerometer type gyroscope will provide a peak in a first, e.g. positive, direction for a leftward rotation of the user's head and a second, e.g. negative, peak for opposite, rightward direction of the user's head.
20 These would provide positive and negative values for an integral of the signal. Thus, left and right motion can easily be determined by a positive value for leftward movement and a negative value for rightwards movement. The amount of the integral provides the amplitude of the
25 rotation in that given direction.

Normally, in use, following a rotation of his head, a user
14 will return his head to the central position with his head pointing forward. In addition, a user will typically
30 have his head pointing forwards for the majority of the time. Both of these facts can be used to provide a resetting mechanism for the head rotation detection mechanism 10 which can be set to have the forward

direction as the direction used for the majority of the time.

An alternative method by which head rotation can be
5 detected would be to use the analysis of high frame rate
imagery from a camera view in line with the user's head in
order to detect head rotation from the motion field of the
video. Taking a camera 16 as shown in Figure 1a, which
captures images at a high frame rate, movement of the
10 image is detected. For example images may be coded with an
MPEG standard, in which a difference between successive
images is calculated and coded, rather than coding the
whole image for each "frame". By taking a crude average
of the position of selected blocks within an image and
15 analysing how those blocks move across the screen, an
estimate of head rotation speed can be obtained. More
specifically, corner points or edges of objects within the
field of view can be detected and located and then tracked
across the field of view to give an estimate of an amount
20 rotation of a user's head. This latter method would need
a reasonable degree of focus in order to be able to detect
corner points. Further information can be obtained from
Comparing and Evaluating Interest Points; Cornelia
Schmid, Roger Mohr, and Christian Bauckhage; INRIA Rhône-
25 Alpes, 655 av d'Europe, 28330, Montbonnot, France.

Together with detection of head motion/rotation, it is
also necessary to have a controllable field of view for
image capture. A number of alternatives are possible.
30

The first alternative is to use multiple cameras angled in
fixed orientation such that a captured image can be
switched automatically from one to other camera, with the

possibility of forming a view from an intermediate angle of view by forming a composite from parts of an adjacent pair of cameras. Figure 1a and Figure 1b show a central camera 16, a left camera 18, and a right camera 20 having the fields of view shown schematically in Figure 1b. The fields of view clearly overlap.

The embodiment shown in Figures 1a and 1b would typically be used by recording the central camera 16 when a wearer's head is not rotating, with the other cameras 18 and 20 being ignored. When rotation of the user's head to the left for example is detected by the motion detection device 10 recording the image is switched to camera 18. When the user's head returns to the centre position, as detected by the motion detector sensor 10, recording is switched to the central camera 16. Similarly, when a right turn of the head is detected recording is switched to the right camera 20 and back to the central camera 16 when the user's head moves back to the centre position.

The pair of spectacles 12 shown in Figures 1a and 1b carries the three cameras 16, 18 and 20 and the motion detection device 10. The motion detection device may be located on an arm 13 of the spectacles to be less obtrusive. Also, a control and image recording apparatus 22a may be located on the glasses. Alternatively, images may be transmitted to a remote control and image storage section 22b, for example by a wireless link, such as a Blue Tooth link, or by a wired link.

Typically, the spectacles 12 incorporating the cameras 16, 18, 20 and motion detection means 10 will continuously capture images from one of the cameras 16, 18, 20. Frames

may be deliberately dropped when there is excessive head motion if the exposure time cannot be kept sufficiently high to avoid motion blur. The frames may be stored continuously as a video, or they may be held in a temporary rolling buffer such that a predetermined number of the last images is recorded. In this case, the user would typically signal to the camera when something that should be recorded had just been observed. On receiving the signal the control/storage apparatus 22a or 22b would transfer the current contents of the rolling buffer to its permanent storage, also located in the control/storage section 22a/22b.

Normally, following a rotation of the head, the camera wearer will return his head to the central position within a short time. This can be detected by the head rotation sensor 10 to cause the image capture to revert to the centrally positioned camera 16. If a return rotation is not detected within a short time, typically in approximately 2 seconds, the controller/storage apparatus 22a/b automatically returns to recording of the central view from camera 16, because it is unlikely that the wearer will keep his eyes far from straight for a prolonged time. Instead, the body is likely to be turned towards the direction of interest.

This automatic return to centre may be implemented by a simple time-out mechanism. Alternatively, the system may revert to centre when it has a high confidence that an image of acceptable quality has been captured, looking in an extreme direction. Such a confidence measure can be a function of camera motion, exposure and focus parameters for example, by which it may be determined whether the

camera has been stationary for long enough for a suitable image to be captured.

The multiple sensor implementation shown in Figures 1a and 5 1b has the advantage that images from the side views can be captured immediately. This is typically important because it is likely to have been an interesting event which the wearer saw "out of the corner of his eye" which attracted his attention and hence gave rise to head 10 rotation. A camera that is already pointing in the correct direction has a high chance of capturing an image of the event.

Still further, the latter advantage may be further 15 improved by implementing the system so that each of the three cameras 16 to 20 in Figures 1a/b is locally buffering images to the storage/control section 22a/b, with only one camera output being retained. When inputs to the system of the motion sensors to control section 20 22a/b indicate that images should be captured the buffered images could be taken from a time fractionally earlier than the detection time. In this way, the view that caused the user to turn his head will be caught before he actually turned.

25

The advantages of the embodiment shown in Figures 1a/b could be improved by using sufficient cameras with overlapping fields of view that at least one of them will always capture an image which has reasonable framing. If 30 an insufficient number of cameras is used, then framing may not be adequate. Also, a sufficiently fast exposure should be used such that images free from motion blur are captured even whilst the user's head is rotating. In this

way, an acceptably cropped still image will be obtained by at least one of the frames captured during the head rotation. Alternatively by using the three cameras shown in Figures 1a and 1b frames may be combined from adjacent
5 cameras by using any of the well-known mosaicing techniques in order to generate an image with an intermediate direction of view, but which is better framed.

10 As an alternative to the three cameras 16 to 18 shown in Figures 1a/1b, it is possible to arrange a pan/tilt mechanism 24 for a camera 26 to be mounted the user's head, as shown in Figures 2a/b. A pan/tilt mechanism similar to the one described in Wearable Visual Robot
15 (above) could be used.

The pan/tilt mechanism 24 is controlled in the same way that camera selection is made in the previous example, except that when a side view (left or right) is required
20 the pan/tilt mechanism 24 moves the camera 26 to the side by a given angle. The angle use may be approximately in the range of approximately 30° to approximately 45° , which corresponds to an angle through which a user's eyes may typically move when glancing sideways to follow a
25 movement.

A further alternative would be to use a system shown in Figure 3 by which first and second fixed sensors 28 and 32 have an optically rotatable or switchable direction of
30 view. This system is effectively like a periscope on its side, with a moveable mirrors 30 that can be rotated (as shown by the arrows) in order to change the image that is reflected towards the sensors 28/32 from a view V. The

two sensors 28/32 may face towards a centre part of the spectacles shown in Figure 4a. The mirror 30 (or a mirror for each sensor) may be rotated to change the field of view reflected to the sensors 28/32. Mirror 28 may
5 reflect for a right hand field of view and the other mirror (not shown) for a left hand field of view. An alternative arrangement would use a single mirror.

For the embodiment described above, the arrangements
10 described in Figures 2a, 2b and 3 have the advantage that the number of components is reduced, because fewer image sensors are required. However, there may be some time lag disadvantage with these embodiments, because of the time required to sense the need for movement to one side and
15 the time to achieve that movement.

A further alternative for controlling the field of view of the image capture device, would be to have automated cropping of an image from a camera 40 with a very wide
20 field of view 42 (see Figure 4a). This would need a high resolution sensor 44 and would also typically use a fish-eye lens 46 or the like. A window of interest 48, as detected and defined by a user's head motion in the manner described above could then be moved across the captured
25 field of image 42 to retain that part of the image which is decided to be of interest.

An advantage of this latter controllable field of view is that there are no moving parts. In the function required
30 by the system described herein good image quality is required at the periphery of an image also, because that may become the centre of a chosen field of interest 48 within the image 42.

A more sophisticated implementation of the systems described above would be to include an additional mechanism for detecting rotation of the user's body. Such
5 a mechanism would allow head motion relative to the body to be identified. The mechanism used would be the same as that used to detect head rotation, but merely secured to the user's body instead of his head. This would allow the head motion relative to the body to be identified. With
10 this embodiment an offset view angle can be chosen on the basis of the measured head rotation relative to the measured body rotation. This embodiment has the advantage of being a more accurate indicator of when the additional rotation of view should be started and terminated, because
15 it may be used to prevent inappropriate changes to the camera field of view. For example if a wearer is walking around a corner, he may look straight ahead so no change of the field of view is required. The addition of a body rotation sensor allows this situation to be differentiated
20 from that of a head turn alone, the latter signifying a change of view..

Another use of this embodiment is in the case where the head turns initially relative to the body, but the body
25 then turns by a matching amount, so that head and body are facing the same way. The time at which the body "catches up" can signify that the focus of attention has reverted to straight ahead, so the additional rotation of the camera's field of view can be terminated when this
30 condition is detected, if it has not been detected earlier.

It would be optional for any of the methods for capturing images described above to be left as a final choice to a user, or a best frame technique could be used to automatically pick the angle of view which best frames a
5 probable subject.

All of the embodiments described above advantageously provide means by which a user can automatically capture an image of a subject of interest to which his attention is
10 drawn and to which he is moving his eyes relative to movement of his head.

CLAIMS:

1. An image capture system incorporates an image capture device and head motion detection means operable to detect motion of a user's head, wherein the image capture system is adapted to move a direction of a field of view of the image capture device relative to the user's head, based on detected motion of the user's head.
2. An image capture system as claimed in claim 1, in which the image capture device is operable to be mounted on a user's head.
3. An image capture system as claimed in either claim 1 or claim 2, in which the head motion detection means are adapted to be secured to the user's head.
4. An image capture system as claimed in any preceding claim, in which the head motion detection means are operable to detect rotation of the user's head.
5. An image capture system as claimed in any preceding claim, in which the head motion detection means are mechanical head motion detection means.
6. An image capture system as claimed in any preceding claim, in which the head motion detection means incorporate a centering mechanism.
7. An image capture system as claimed in any preceding claim, in which the image capture system is operable to control the direction of view of the image capture device with field of view control means.

8. An image capture system as claimed in claim 7, in which the field of view control means comprise at least one additional image capture device.

5

9. An image capture system as claimed in claim 8, in which the or each additional image capture device is a lateral image capture device, which has a field of view to one side of a main image capture device that substantially partially overlaps with a field of view of the main image capture device.

10. An image capture system as claimed in claim 8 or claim 9, in which images from the main and additional image capture devices are buffered in a storage means for subsequent retention of an image/images from one of said image capture devices.

11. An image capture system as claimed in claim 7, in which the field of view control means comprise a mechanism operable to adjust a direction of the image capture device.

12. An image capture system as claimed in claim 7, in which the field of view control means comprise at least one mirror operable to be adjusted to adjust an image reflected to the image capture device.

13. An image capture system as claimed in claim 7, in which the field of view control means are operable to select a smaller image from a first image captured by the image capture device.

14. An image capture system as claimed in any one of claims 7 to 13, in which the image capture system incorporates control means, operable to activate the field of view control means on detection of movement of the user's head.

15. An image capture system as claimed in claim 14, in which, on detection of movement of the user's head in a first direction by the head motion detection means, the control means is operable to activate the field of view control means to move a direction of view of the image capture device in the first direction, by an amount in addition to the detected head motion.

16. An image capture system as claimed in any preceding claim, in which an amplitude of movement of the user's head detected by the head motion detection means is used to control an amplitude of movement of the direction of view of the image capture device in addition to the detected head motion.

17. An image capture system as claimed in any preceding claim, in which a direction of detected head movement is used to select an additional image capture device for providing the field of view.

18. A method of capturing an image from an image capture device, comprises:

detecting motion of a user's head; and
offsetting a field of view of an image capture device in a direction of the detected motion of the user's head.

19. A method as claimed in claim 18, in which the image capture device is secured to the user's head.

20. A method as claimed in either claim 18 or claim 19, in
5 which the detected motion is a rotation of the user's head.

21. A method as claimed in any one of claims 18 to 20, in
10 which the field of view is offset by an amount derived from an amplitude of the detected motion.

22. An image capture system substantially as described herein with reference to the accompanying drawings.

15 23. An method of capturing an image from an image capture device substantially as described herein with reference to the accompany drawings.

Abstract**Image Capture Systems using Motion Detection**

An image capture system incorporates an image capture
5 device (16) and head motion detection means (10) operable
to detect motion of a user's head, wherein the image
capture system is operable to move a field of view of the
image capture device (16) based on a detected head motion.

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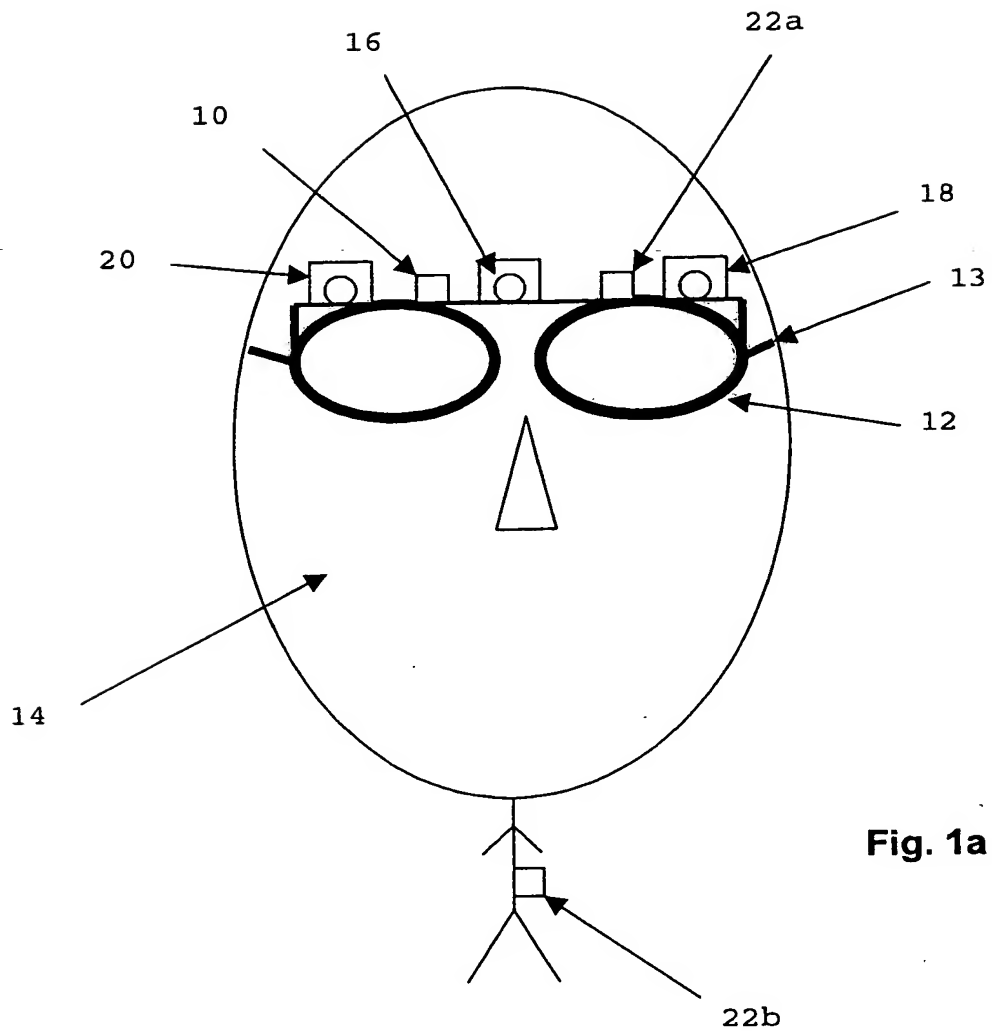


Fig. 1a

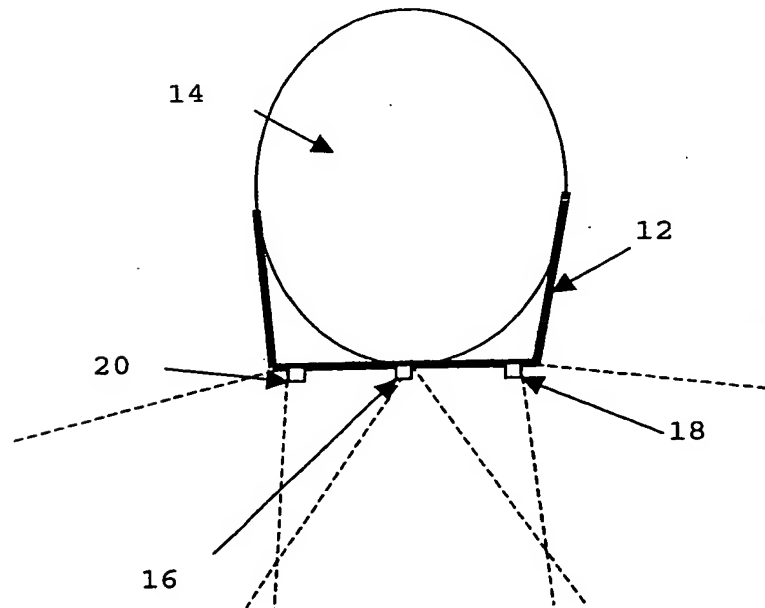


Fig. 1b

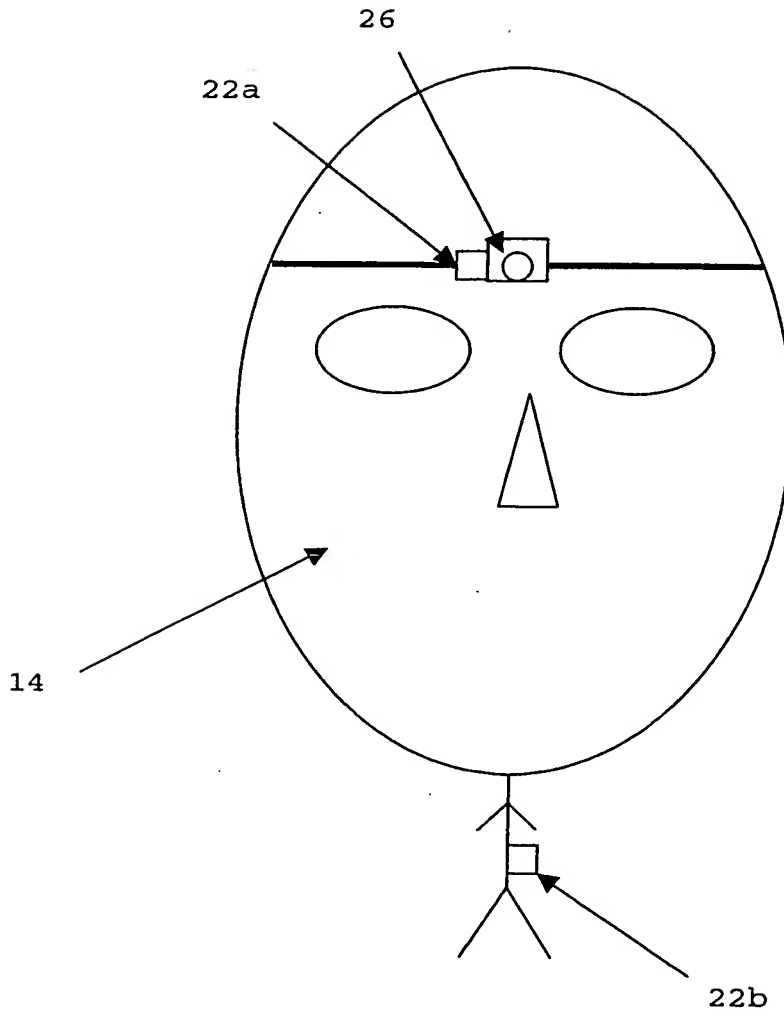


Fig. 2a

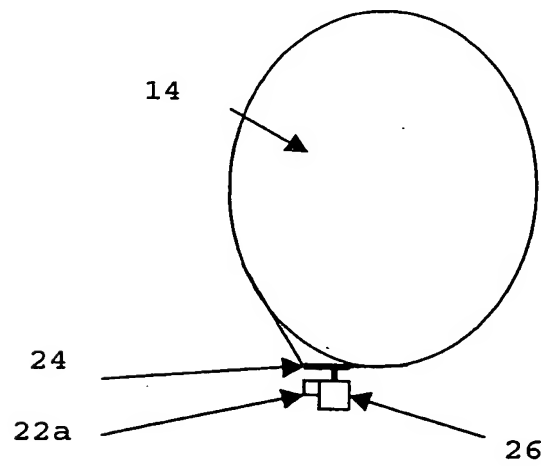


Fig. 2b

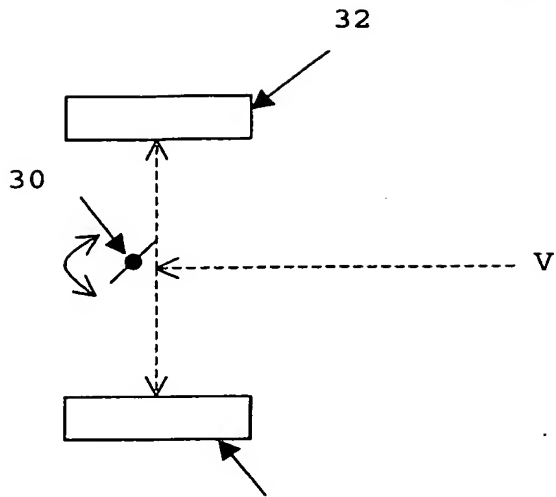


Fig. 3

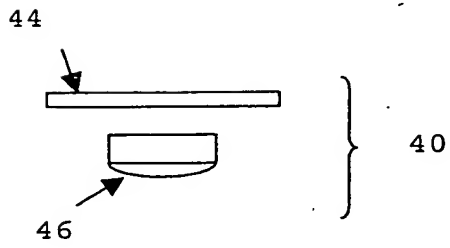


Fig. 4a

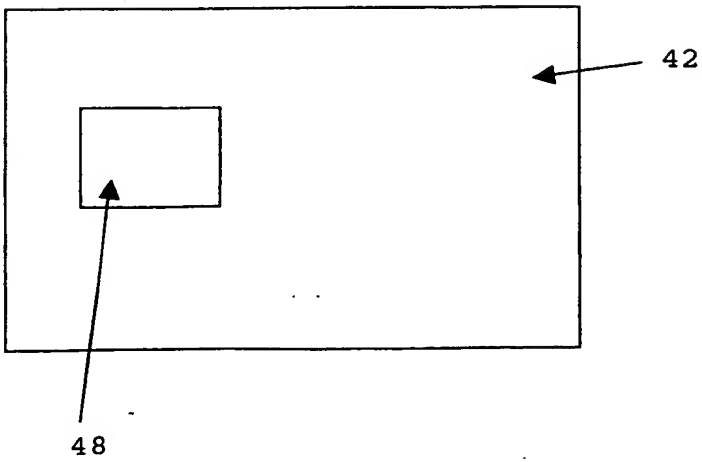


Fig. 4b